INCLUSIVE K_s^0-PRODUCTION IN e^+e^- ANNIHILATION AT ENERGIES OF 3.6 TO 5.0 GeV

PLUTO-Collaboration

J. BURMESTER, L. CRIEGEE, H.C. DEHNE, K. DERIKUM, R. DEVENISH, J.D. FOX, G. FRANKE, G. FLÜGGE, Ch. GERKE, G. HORLITZ, Th. KAHL, G. KNIES, M. RÖSSLER, R. SCHMITZ, U. TIMM, H. WAHL[1], P. WALOSCHEK, G.G. WINTER, S. WOLFF, W. ZIMMERMANN

Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

V. BLOBEL, H. JENSING, B. KOPPITZ and E. LOHRMANN[2]

II. Institut für Experimentalphysik der Universität Hamburg, Hamburg, Germany

A. BÄCKER, J. BÜRGER, C. GRUPEN, M. ROST, G. ZECH

Gesamthochschule Siegen, Siegen, Germany

and

H. MEYER and K. WACKER

Gesamthochschule Wuppertal, Wuppertal, Germany

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We have measured the production cross section for K_s^0 in e^+e^- annihilation from 3.6 to 5.0 GeV center of mass energy. A substantial increase of the K_s^0 yield is observed around 4 GeV in qualitative agreement with the charm hypothesis.

The total cross section for e^+e^- annihilation into hadrons (σ_h) normalized to the muon pair cross section ($\sigma_{\mu\mu}$) shows a clear step of about two units at 4 GeV center of mass energy. In addition the total cross section is not flat above 4.0 GeV but shows considerable structure [1, 2]. This is usually attributed to the production of pairs of charmed quarks, adding $3 \times (2/3)^2$ units of $R = \sigma_h/\sigma_{\mu\mu}$ to the total cross section. The charmed quarks then fragment into a pair of charmed hadrons which subsequently decay by weak interaction preferentially into strange particles. A sizeable increase in kaon production is then expected above threshold for charmed particle production. Furthermore the resonance like structures in the total cross section at 4.03 and 4.415 GeV are assumed to have strong coupling to charmed hadrons. This should be detectable by measuring the strange particle yield in this energy region.

We have measured the K_s^0-production in e^+e^- annihilation into hadrons using the magnetic detector PLUTO at the e^+e^- storage ring facility DORIS at DESY. Results on K_s^0-e correlations [3] as evidence for the semileptonic decay mode of charmed particles and on the total cross section [2] have been reported. Reference should be made to those papers for details of the experimental procedure. Briefly, the detector uses a superconducting solenoid to produce a field of 20 kΓ. The field volume is filled with 14 cylindrical proportional chambers used for triggering and reconstruction of events. The luminosity is measured by small angle $e^+e^- \to e^+e^-$ scattering, as determined by four counter telescopes. The detection efficiency for hadronic events is ~ 80%.

We have searched for K_s^0-production by calculating the effective mass of oppositely charged pairs of particles assuming they are pions. To suppress background from normal pion pairs a minimum distance of 15 mm from the decay vertex to the e^+e^- interaction point was required. A vertex fit is made constraining the momentum vector of the pion pair to the interaction point. The mass distribution for pion

[1] On leave from CERN.
[2] Now at CERN.

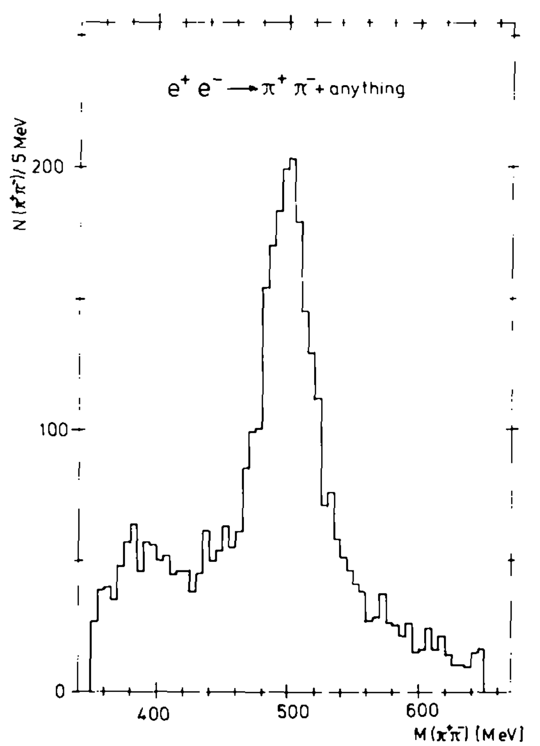

Fig. 1. Mass distribution of $\pi^+\pi^-$ pairs with a vertex outside the e^+e^- interaction point (see text).

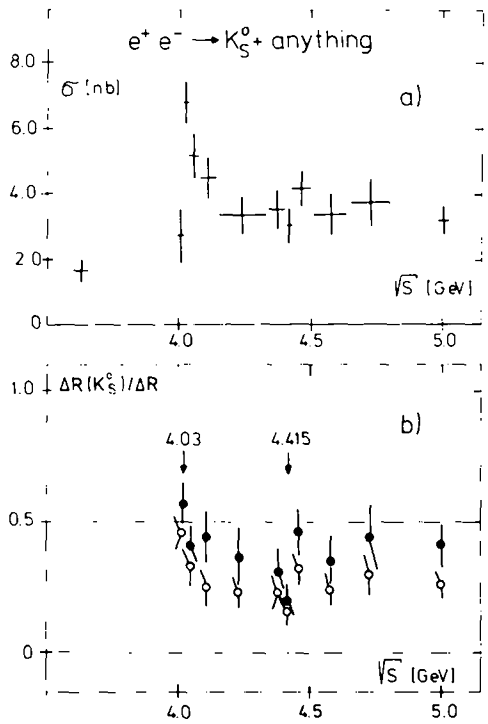

Fig. 2. (a) The cross section for $e^+e^- \to K_S^0$ + anything as function of the total center of mass energy. No radiative corrections have been applied. (b) The number of K_S^0 per new event $\Delta R(K_S^0)/\Delta R$ (ϕ); (♦) accounting for a heavy lepton contribution.

pairs satisfying the above criteria is shown in fig. 1. The background below the K_S^0 mass has been estimated from side bins and subtracted for all the following plots. The efficiency to find a $K_S^0 \to \pi^+\pi^-$ with this method is momentum dependent and has been determined by a Monte Carlo study. The production angular distribution was assumed to be isotropic. The detection efficiency is essentially zero below 150 MeV/c. It rises smoothly, and goes through a maximum of 21% at 1 GeV/c. We cut at 200 MeV/c, and apply no correction for the loss of lower momentum kaons. The loss can be estimated by extrapolating the observed momentum dependence to zero momentum, and amounts to ~ 10% of the observed yield. Trigger losses not accounted for in the Monte Carlo calculations are estimated to be less than 10%. The data have been corrected for the unobserved decay mode $K_S^0 \to \pi^0\pi^0$.

Sizeable K_S^0 production is found at all energies. The cross section for inclusive K_S^0 production is shown in fig. 2a. A prominent peak at 4.03 GeV is observed. For higher energies the K_S^0 cross section shows little structure but has a higher level than at 3.6 GeV.

The increase in K_S^0 production is dominantly due to kaons with energies less than half the beam energy. This is evident from fig. 3a, b, where we show the invariant cross section $(s/\beta)\cdot d\sigma/dx$ versus $x = E(K_S^0)/E(\text{beam})$, at $\sqrt{s}$ = 4.03 GeV and $\sqrt{s} > 4.03$ GeV each compared to the data at $\sqrt{s}$ = 3.6 GeV. At $x > 0.5$ the spectra are seen to be fairly similar, as expected in quark fragmentation models.

Discussion. The excess K_S^0 which we observe at $\sqrt{s}$ = 4.03 GeV as compared to $\sqrt{s}$ = 3.6 GeV are concentrated at $x < 0.5$. This supports the hypothesis that they come from the decay of intermediate charmed pairs. Since the K_S^0 increase is largest for the very small x values we infer a dominance of multibody decays in agreement with previous indications [3–5].

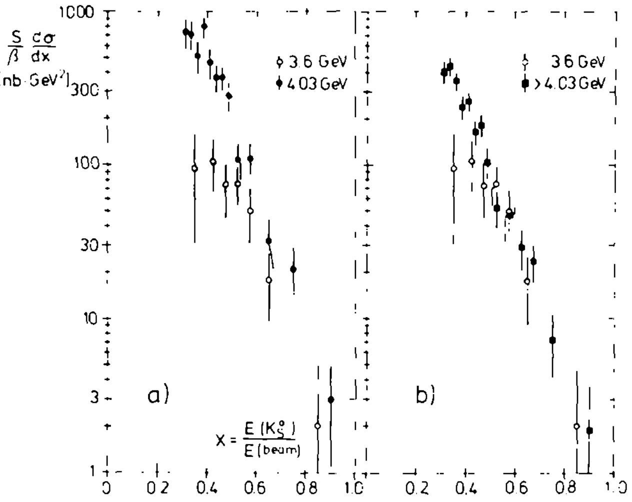

Fig. 3. (a, b) The invariant cross section $(s/\beta)\, d\sigma/dx$ versus x for 3.6 GeV (ϕ), 4.03 GeV (⧫) and (⧫) > 4.03 GeV.

We next determine the kaon yield per annihilation event above threshold for charmed particle production. We do so in the spirit of the quark model for e^+e^- annihilation into hadrons. The basic mechanism is assumed to be the production of a pair of quarks which subsequently fragments into hadrons. Above $\sqrt{s} = 4$ GeV, we use the following expression for the normalized total cross section:

$$\sigma_h/\sigma_{\mu\mu} = R(\text{hadron}) = R_{q\bar{q}} + R_{c\bar{c}} + R_{L\bar{L}} . \tag{1}$$

The symbol q refers to n, p, λ quarks and c refers to the charm quark. A contribution $R_{L\bar{L}}$ due to the production of heavy leptons has been included. Evidence for this lepton has been reported by the SLAC-LBL group [6] and has been confirmed by a recent PLUTO experiment [7].

Eq. (1) can also be written for the inclusive K_s^0 cross section.

$$\sigma(K_s^0)/\sigma_{\mu\mu} = R(K_s^0) = R_{q\bar{q}}(K_s^0) + R_{c\bar{c}}(K_s^0) + R_{L\bar{L}}(K_s^0), \tag{2}$$

$R_{q\bar{q}}$ and $R_{q\bar{q}}(K_s^0)$ have been determined at $\sqrt{s} = 3.6$ GeV and are assumed to be independent of $\sqrt{s}$. The new part ΔR due to the charm and heavy lepton contribution is then given by

$$\Delta R = R - R_{q\bar{q}}(\sqrt{s} = 3.6).$$

The ratio $\Delta R(K_s^0)/\Delta R$ is the number of K_s^0 per new event. Using our measured total cross section‡ and the K_s^0 cross section in fig. 2a we calculate $\Delta R(K_s^0)/\Delta R$ shown in fig. 2b (open points). No radiative corrections have been applied since they should approximately cancel in the ratio. The contribution due to the heavy lepton is expected to yield very few kaons [8]. With the assumptions $R_{L\bar{L}}(K_s^0) = 0$ and $M(L) = 1.95$ GeV we determine the number of K_s^0 per charm event (full points in fig. 2b). Assuming $2\cdot N(K_s^0) = N(K^0 + \overline{K^0}) = N(K^+ + K^-)$ as supported by a recent experiment [9], we expect $N(K_s^0)$/charm event = 0.5 (neglecting the Cabbibo angle). The data points, taking into account the heavy lepton contribution (full points), are slightly less than this prediction.

In the total cross section resonance like structures have been observed at 4.03 and 4.415 GeV [1, 2]. At both energies we have taken fairly large data sets. Comparing the normalized K_s^0 yields at the two energies (see the arrows in fig. 2b), we have an indication of substantially less K_s^0-production at 4.415 GeV.

In conclusion we find a significant increase of K_s^0 yield going from $\sqrt{s} = 3.6$ GeV to $\sqrt{s} > 4.0$ GeV. This is very well compatible with the charm hypothesis. Just above threshold, at $\sqrt{s} = 4.03$ GeV, we find a stronger K_s^0 production than at higher energies, and there is an indication for a reduced relative K_s^0 production at the position of the 4.415 GeV resonance.

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‡ Values are taken from ref. [2] and from more recent data (unpublished).

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